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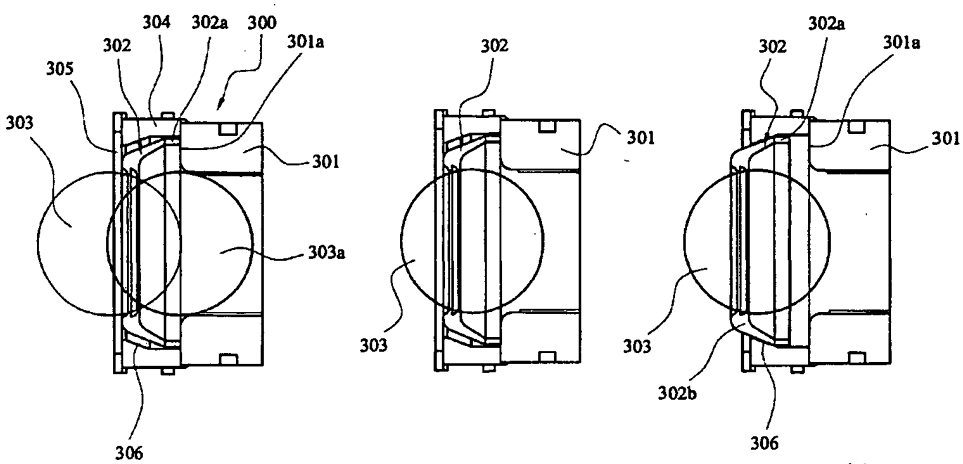
(54) Title: BALL ACTIVATED TOOL FOR USE IN DOWNHOLE DRILLING



(a) (b) (c)

(57) Abstract: A ball activated tool (1) for use in dowhole drilling, said tool being adapted to be mounted in a casing portion of a drill string, in which the tool comprises: a hollow main body (1); outlet port means (5) in the wall of the main body (1) through which fluid can flow transversely of the drill string; a control sleeve (6) slidably mounted in the main body; and, a ball seat arranged at one end of the sleeve (6) to receive a deformable ball (20,104) when the latter is launched down the drill string to activate the tool, which ball seat (100) includes: a deformable annular member (101) , and an abutment (102) which is spaced axially from the annular member (101) by a sufficient distance to allow the abutment (102) and the annular member (101) to co-operate to latch the ball (104) against axial movement inwardly or outwardly of the ball seat (100).

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BALL ACTIVATED TOOL FOR USE IN DOWNHOLE DRILLING

This invention relates to a ball activated tool for use in downhole drilling.

During drilling for below-ground fluids, such as gaseous and / or liquid hydrocarbons, it is usual to employ a drill string, at the lower end of which a drilling head carries out drilling operations through the strata of rock and other solid formations, and to supply drilling fluid (mud) to the drilling or working end of the drill string via a so-called "downhole valve".

It is known from US 4889199 and 5499687 to provide a downhole valve in a drill string, and which comprises a tubular casing for mounting in the drill string, and which allows through-flow of fluid during normal drilling operations.

There is first outlet means in the casing for discharging fluid laterally outwardly from the casing, and a sleeve slidably mounted in the casing and biassed by a spring to a closed position in the casing in which the sleeve closes the first outlet means. There is also second outlet means in the sleeve for discharging fluid from the sleeve when the first and second outlet means are aligned.

There is also provided a first ball (which is a large deformable ball of plastics material), which can be dropped down the drill string, i.e. launched from the surface, and which can be driven by pressure of the drilling fluid to a position of engagement with the downhole valve in order to adjust its operation. In particular, the large ball can engage the sleeve and cause it to move relative to the casing into an open position in which the first and second outlets are aligned in order to discharge fluid laterally through the casing e.g. in order to inject lost circulation material into the surrounding formation when fluid is being lost to the formation.

Furthermore, a second smaller hard-ball (a de-activating ball) can then be dropped down the drill string and which first blocks the second outlet so that pressure on the first and second balls then increase sufficiently to drive the first (deformable) ball through the sleeve, when it is required to restore normal flow of drilling fluid through the sleeve and for allowing a return of the sleeve to the closed position (blocking communication between the first and second outlet means).

During a typical drilling operation, the drill string moves substantially vertically downwardly through the various rock formations, but as the head of the drill string approaches potential producing formations, it is often the case that the lower working end or drilling head is steered in a lateral direction, and even in some cases in a substantially horizontal direction, in order to reach the producing formation.

When the downhole valve is located in a vertical, or near vertical orientation of the casing in which it is mounted, it is a simple matter to activate and de-activate the valve, by launching the first and second balls from surface and which move downwardly under gravity action, and possibly assisted by the pressure of the drilling mud. However, in the event that the casing in which the downhole valve is mounted moves into a transversely extending bore-hole, the balls launched from the surface can no longer rely upon the action of gravity to maintain the ball concerned in engagement with the sleeve.

The present invention is therefore primarily concerned with the provision of an improved valve seat, engagable by a ball launched from the surface to activate the downhole tool and which allows the activating ball (which is deformable) to move through the valve seat, without any significant deformation and to take up a latched position.

According to the invention there is provided a ball activated tool for use in downhole drilling, said tool being adapted to be mounted in a casing portion of a drill string and being moveable with the casing during a drilling operation, in which the tool comprises:

a hollow main body through which axial flow of fluid can take place between an inlet end and an outlet end of the main body and lengthwise of the drill string, in a first mode of operation;

outlet port means in the wall of the main body through which fluid can flow transversely of the drill string, in a second of mode of operation;

a control sleeve slidably mounted in the main body for movement between a first position in which it blocks communication between an interior of the main body and said outlet port means, and a second position in which it allows communication between the interior of the main body and the outlet port means;

means biassing the control sleeve towards said first position; and,

a ball seat arranged at one end of the sleeve to receive a deformable ball when the latter is launched down the drill string to activate the tool, said seat being operative when engaged by the launched ball to move the sleeve to the second position and against the biassing means, and said ball being capable of deforming under load so as to be moveable lengthwise of the sleeve and thereby allow the tool to be de-activated;

in which the ball seat includes:

1. A deformable annular member which defines a through-opening, which (a) in the un-deformed state of the annular member is too small to allow through-passage of the deformable ball (without deformation of the ball), but (b) which is deformable, when the ball applies a pre-determined axial load to the seat, to allow the ball to pass through the annular member and substantially without deformation of the ball; and,

2. an abutment which is spaced axially from the annular member by a sufficient distance to allow the ball to move through the annular member, when the latter is in its deformed state and into engagement with the abutment, the annular member then being capable of reverting to its undeformed state whereby the abutment and the annular member co-operate to latch the ball therebetween against axial movement inwardly or outwardly of the ball seat.

The invention therefore provide a new ball seat arrangement, in a ball activated tool for use in downhole drilling, which holds the ball in a latched position after it has been launched down a drill string and into engagement with the ball seat to activate the tool, even in circumstances in which gravity action alone would not be sufficient to hold the ball against the ball seat, e.g. when the drill string is moving in a non-vertical direction.

In one embodiment, the annular member may comprise a circumferentially split ring which is slidably mounted on a conical mounting face which increases in diameter axially inwardly of the ball seat, the spilt ring then being radially expanded as it is moved by the ball on the conical mounting face, so that the opening increases in diameter by a sufficient amount to allow the ball to pass through the opening.

In a further embodiment, the annular member may comprise a disc spring with an outer annular flange and an inner annular portion which is divided by radial slits into separate portions, such portions being deformable axially by the ball in order to increase

the diameter of the through-opening defined by the portions and allow the ball to move through the opening substantially without deformation, and then take up the latched position.

The abutment of the ball seat may be formed by a shoulder on the leading end of the axially moveable sleeve, and preferably taking the form of a circular shoulder. However, it should be understood that other shapes and arrangements of the "abutment" of the invention may be used, provided that the required functional properties are obtained, namely to act in concert with the annular member in order to "latch" the ball against axial movement inwardly or outwardly of the ball seat.

The tool of the invention, which is mountable in a casing portion of a drill string may comprise any downhole tool which is required to be activated by the launching of a ball from surface, but in one preferred form comprises a downhole valve of the type described in more detail in US Patent 4889199 and 5499687.

Preferred embodiments of ball activated tool for use in downhole drilling will now be described in detail, by way of example only, with reference to the accompanying drawings, in which:

Figures 1 to 4 are partly sectional side views of a downhole valve for use in a drill string, and to which the invention may be applied, such figures comprising the downhole device disclosed in more detail in US Patent 4889199;

Figure 5 is a sectional side view of an improved ball seat which may be incorporated in a ball activated downhole tool, to form a first embodiment of the invention, and showing the initial engagement of a ball launched from the surface with the internal components of the ball seat;

Figure 6 is a view, similar to Figure 5, showing a latched position taken up by the ball after it has activated the tool and is held against axial movement both inwardly and outwardly of the ball seat by the internal components;

Figure 7 illustrates in more detail the construction of a deformable annular member of the ball seat shown in Figures 5 and 6;

Figure 8 is a sectional side view of a second embodiment of improved ball seat for incorporation in a downhole tool according to invention;

Figure 9 is an exploded view of the internal components of the ball seat shown in Figure 8;

Figure 10 illustrates a third embodiment of the invention, with Figures a, b and c showing successive stages of activating of the ball seat arrangement, in a 4 3/4 BPL; and,

Figure 11 illustrates a fourth embodiment of the invention, with views a, b and c showing successive stages of activating of the ball seat, and provided in a 6 ½ BPL.

The downhole device disclosed in US Patent 4889199 will now be described briefly, with reference to Figures 1 to 4, to give one example of a downhole tool to which the invention may be applied.

With reference to Figures 1to 4 the downhole device is a bypass sub defined by a tubular casing (1) with an internally threaded top end (2), and an externally threaded bottom end (3) for mounting the casing (1) in a drill string. An outlet opening (5) is provided on one side of the casing (1) for discharging fluid from the interior of the casing. The opening (5) is normally closed by a sleeve (6) which is slidably mounted in the casing (1). 0 rings (7) above and below the opening (5) provide fluid seals between the casing (1) and the sleeve (6). The sleeve (6) is retained in the casing (1) by a retainer ring (9) mounted in the casing beneath the threaded top end (2) thereof. Downward movement of the sleeve (6) in the casing is limited by a shoulder (10) on the sleeve (6) and a ledge (12) on the interior of the casing (1). Vertical movement of an annular floating piston (13) is facilitated by movement of the sleeve (6). A chamber containing a spring (16), i.e. the chamber defined by the bottom, outer wall of the sleeve (6), the interior casing (1), the shoulder (10) and an annular ledge (17) contains hydraulic fluid. Rotation of the sleeve (6) in the casing (1) is prevented by a guide pin (14) extending radially inwardly through the casing (1) into a longitudinally extending slot (not shown) in the outer surface of the sleeve (6). The sleeve (6) is biassed to the closed position over the opening (5) by the helical spring (16), which extends between the shoulder (10) and the annular ledge (17) above the guide pin (14). An outlet opening (18) is provided in one or more sides of the sleeve (6) the outlet opening (18) being vertically aligned with the opening (5) in the casing (1).

During a lost circulation condition i.e. when drilling fluid is being lost to the formation, and it is desired to inject lost circulation material into the formation, the drill

string is broken at the surface, and a large plastic ball (20) is placed therein. The ball (20) descends to the casing (1) (i.e. to the bypass sub). The ball (20) can be pumped through a portion of the drill string above the casing (1) in order to speed up feeding of the ball. However, pumping should be stopped at least two barrels before the ball (20) reaches the casing (1) (Figure 2). Subsequently, the ball engages an inwardly inclined shoulder (21) on the interior of the sleeve (6). The pump pressure in the drill string causes the ball (20) to push the sleeve (6) downwardly against the force of the spring (16) until the shoulder (10) engages the ledge (12). In this position, the openings (5) and (18) are aligned, so that lost circulation material such as woodchips can be discharged into the formation. Once the formation has been sealed, the string is again broken at the surface, and a smaller metal ball (23) (Figure 3) is dropped into the string. Pumping is then continued to cause the metal ball (23) to bear against the opening (18). Continued pumping of drilling mud into the casing (1) forces the balls (20) and (23) downwardly through the sleeve (6) into a ball catcher device generally indicated at (25). This procedure can be repeated as often as necessary. It is necessary to ensure that all of the loose circulation material is discharged from the casing (1) in order to prevent plugging of the bit jets (not shown).

Referring now to Figures 5to7, this shows a first preferred embodiment of ball seat for use with a ball activated tool for use in downhole drilling. As is well known, a downhole tool, such as a downhole valve, can be mounted in a casing portion of a drill string and is moveable with the casing during a drilling operation. The tool comprises a hollow main body through which axial flow of fluid can take place between an inlet end and an outlet end of the main body and lengthwise of the drill string, in a first mode of operation. Outlet means in the wall of the main body allows fluid to flow transversely of the drill string in a second mode of operation. A control sleeve is slidably mounted in the main body for movement between a first position in which blocks communication between the interior of the main body and the outlet port means, and second position in which it allows communication between the interior of the main body and the outlet port means. Biassing means normally urges the control sleeve towards the first position.

The preferred embodiments of the invention add to a downhole tool the provision of a ball seat which is arranged at one end of the seat to receive a deformable ball when the latter is launched down the drill string to activate the tool, such seat being operative

when engaged by the launched ball to move the sleeve to the second position and against the biassing means.

The ball is capable of deforming under load so as to be moveable lengthwise of the sleeve and thereby allow the tool to be de-activated.

In the two preferred embodiments of the invention disclosed in Figures 5to7, and Figures 8 to 9, the ball seat includes:

1. A deformable annular member which defines a through-opening, which (a) in the undeformed state of the annular member, is too small to allow through passage of the deformable ball (without deformation of the ball), but (b) which is deformable when the ball applies a pre-determined axial load to the annular member, to allow the ball to pass through the annular member and substantially without deformation of the ball.

2. The ball seat also includes a second component in the form of an abutment which is spaced axially from the annular member by a sufficient distance to allow the ball to move through the annular member, when the latter is in its deformed state, and into engagement with the abutment, the annular member then being capable of reverting to its undeformed state whereby the abutment and the annular member co-operate to latch the ball therebetween against axial movement inwardly or outwardly of the ball seat. In the first embodiment shown in Figures 5 to 6, the improved ball seat is designated generally by reference 100 in which the two main components, namely the annular member and the abutment, comprise a circumferentially split ring (101) and a curved shoulder (102) on the leading end of an axially moveable activating sleeve (103). Evidently, other shapes and arrangements of the "abutment" may be used, provided that they have the same capability of co-operating with the corresponding "annular member" in order to "latch the ball.

The circumferentially split ring (101) is shown in Figure 5 in its undeformed state, in which it resists through-movement of ball (104) after the latter has been launched from the surface to activate the tool. Three annular springs (105) are trapped between the ring (101) and the shoulder (102), and normally press the ring (101) axially outwardly of the valve seat to take up the position shown in Fig 6. Figure 5 shows the ring (101) after it has been moved axially inwardly of the ball seat by the ball by the ball 104. During such movement, the ring (101) expands radially outwardly, as it moves along a conical mounting face (106). Figure 5 shows the spilt ring (101) after it has expanded radially by

a sufficient amount to allow through-movement of the ball (104) and substantially without deformation of the ball.

Figure 6 shows the ball (104) after it has moved axially through the opening defined by the split ring (101), and the ball (104) is then trapped or "latched" between the shoulder (102) and the ring (101). It will be noted that the ring (101) has now moved axially outwardly back to its normal ball receiving position, under the action of the springs (105), and ring (101) has now reduced the diameter of its through-opening, thereby to resist axial outward movement of the ball (104).

The ball seat shown in Figures 5 to 7 can be "tuned" to suit different operating conditions, and different types of deformable balls, by appropriate selection of the resilience of the springs (105).

A second preferred embodiment is shown in Figures 8 to 9 and in which the ball seat is designated generally by reference 200. In this embodiment, the annular member comprises a disc spring (201) having an outer annular flange (201a) and an inner annular portion (201b) which is divided by radial slits (201c) into separate portions (201d). The portions (201d) are deformable axially by the ball (204) in order to increase the diameter of the through-opening defined by the portions, and allow the ball (204) to move through the opening substantially without deformation of the ball, and then to take up the latched position between the spring (201) and the curved abutment shoulder (202) provided at the forward end of sleeve 203. The ball seat (200) also includes a spring retainer (207).

Referring now to Figure 10 of the drawings, there is shown a third embodiment of ball seat arrangement according to the invention, designated generally by reference 300. This is intended for incorporation in a 4 3/4 BPL, and has a ball seat 301, and a deformable annular member 302 and Figures a, b and c show successive stages of activating of the ball seal arrangement 300, by means of a large deformable ball 303. An outer housing 304 mounts the deformable annular member 302, and is provided with a circular receiving opening 305 and a sloping shoulder 306 against which the annular member 302 can be seated, as shown in Figure 10c.

Figure 10a shows ball 303 after it has been launched down a drillstring, and in an initial phase of engagement with the annular member 302. The annular member 302 comprises a cylindrical portion 302a, and a displacable conical portion 302b. Figure 10c

shows the cylindrical portion 302a spaced axially away from a contact face 301a of the ball seat 301, whereas Figure 10a shows the cylindrical portion 302a moved axially into contact with the face 301a. Therefore, the initial engagement of ball 303 with the mouth of the annular member 302 moves the annular member 302 axially towards the ball seat 301, to move cylindrical portion 302a into contact with face 301a. Further movement of the ball 303 against the mouth of the annular member 302 causes the conical portion 302b to move radially outwardly, by a sufficient amount to allow the ball 303 to move through the annular member 302 and into engagement with the ball seat 301, as shown in the second illustration of the ball 303, under reference 303a, shown in Figure 10a. The annular member 302 then returns (under spring or other biassing means not described in detail herein) to take-up its initial position, as shown in Figure 10c. The ball 303 will remain in engagement with the contact face 301a as long as there is sufficient pressure on the upstream side and / or under the action of gravity, and the ball is held captive between the ball seat 301 and the annular member 302, although being capable of carrying out limited axial movement in either direction. However, in the event of increase in pressure at the downstream side, i.e. if pumping is carried out in the reverse direction, the ball 303 can unseat itself and move to the position shown in Figure 10c, engaging the ribbed internal face of the mouth of the annular member 302. In this position, the ball seat arrangement 300 still permits by-pass flow of fluid.

Referring now to Figure 11, there is shown a fourth embodiment, generally similar to the embodiment of Figure 10, but provided in a 6 ½ BPL. The ball seat arrangement is designated generally by reference 400, and has a ball seat 401 provided with a profiled receiving nose against which ball 403 can seat, as shown in Figure 11a. A deformable annular member 402 controls the entry and exit of the ball 403, and includes cylindrical portion 402a and hingedly connected conical portion 402b. This fourth embodiment also has the same general function as the third embodiment, and allows by-pass flow to continue, in the event of reverse pumping.

CLAIMS

1. A ball activated tool (1) for use in downhole drilling, said tool being adapted to be mounted in a casing portion of a drill string and being moveable with the casing during a drilling operation, in which the tool comprises:

a hollow main body (1) through which axial flow of fluid can take place between an inlet end (2) and an outlet end (3) of the main body and lengthwise of the drill string, in a first mode of operation;

outlet port means (5) in the wall of the main body (1) through which fluid can flow transversely of the drill string, in a second of mode of operation;

a control sleeve (6) slidably mounted in the main body for movement between a first position in which it blocks communication between an interior of the main body (1) and said outlet port means (5), and a second position in which it allows communication between the interior of the main body (1) and the outlet port means (5);

means (16) biassing the control sleeve (6) towards said first position; and,

a ball seat arranged at one end of the sleeve (6) to receive a deformable ball (20, 104) when the latter is launched down the drill string to activate the tool, said seat being operative when engaged by the launched ball to move the sleeve (6) to the second position and against the biassing means (16), and said ball (20, 104) being capable of deforming under load so as to be moveable lengthwise of the sleeve and thereby allow the tool to be de-activated;

in which the ball seat (100) includes:

a deformable annular member (101) which defines a through-opening, which (a) in the un-deformed state of the annular member is too small to allow through-passage of the deformable ball (104) (without deformation of the ball), but (b) which is deformable, when the ball (104) applies a pre-determined axial load to the seat, to allow the ball to pass through the annular member (101) and substantially without deformation of the ball; and,

an abutment (102) which is spaced axially from the annular member (101) by a sufficient distance to allow the ball (104) to move through the annular member (102), when the latter is in its deformed state and into engagement with the abutment (102), the annular member (101) then being capable of reverting to its undeformed state whereby the

abutment (102) and the annular member (101) co-operate to latch the ball (104) therebetween against axial movement inwardly or outwardly of the ball seat (100).

2. A ball activated tool according to claim 1, in which the annular member comprises a circumferentially split ring (101) which is slidably mounted on a conical mounting face (106) which increases in diameter axially inwardly of the ball seat, the split ring (101) being radially expanded as it is moved by the ball (104) on the mounting face (106) so that the opening increases in diameter by a sufficient amount to allow the ball to pass through the opening.

3. A ball activated tool according to claim 1, in which the annular member comprises a disc spring (201) with an outer annular flange (201a) and an inner annular portion (201b) which is divided by radial slits (201c) into separate portions (201d), such portions (201d) being deformable axially by the ball (204) in order to increase the diameter of the through-opening defined by the portions (201d), and allow the ball (204) to move through the opening substantially without deformation and to take up the latched position.

4. A ball activated tool according to any one of the preceding claims, in which the abutment, (101, 201) is formed by a shoulder on the leading end of the axially moveable sleeve (103,203).

5. A ball activated tool according to claim 1, in which the annular member comprises a cylindrical portion 302a, 402a, movable towards and away from contact with the ball seat 301, 401, and a radially movable conical portion 302a, 402a.

6. A ball activated tool according to claim 5, in which the conical portion 302b, 402b is hingedly connected to the respective cylindrical portion 302a, 402a.

7. A ball activated tool according to any one of the preceding claims and in the form of a downhole valve for controlling the flow of mud to a drilling head of a drill string.

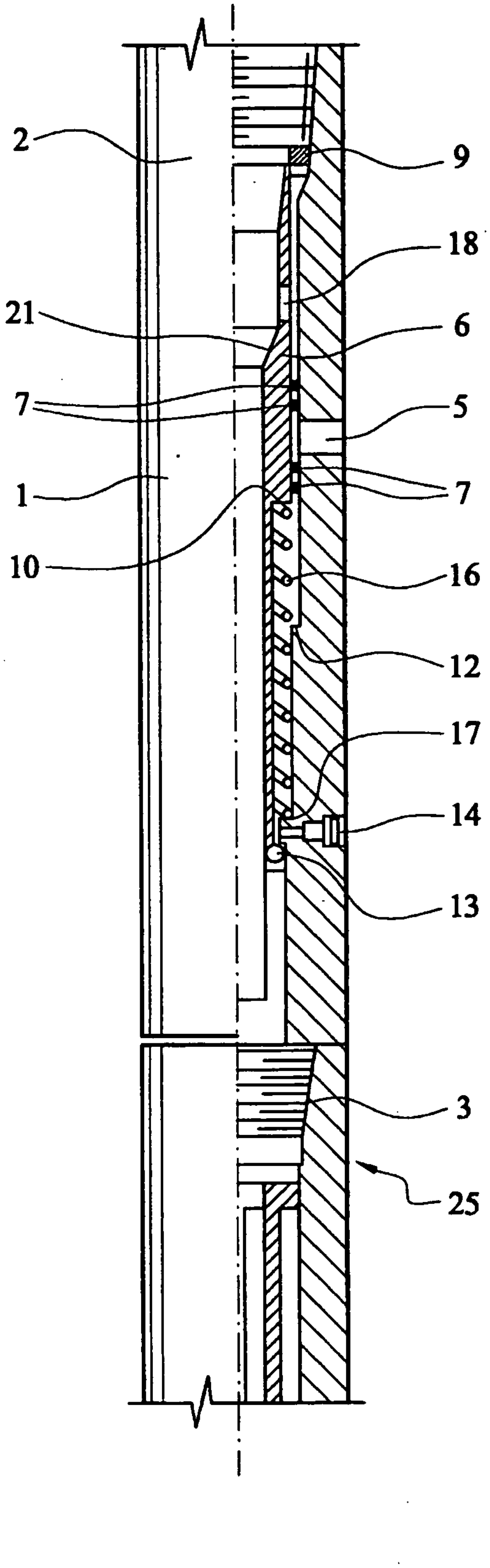
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FIG. 1

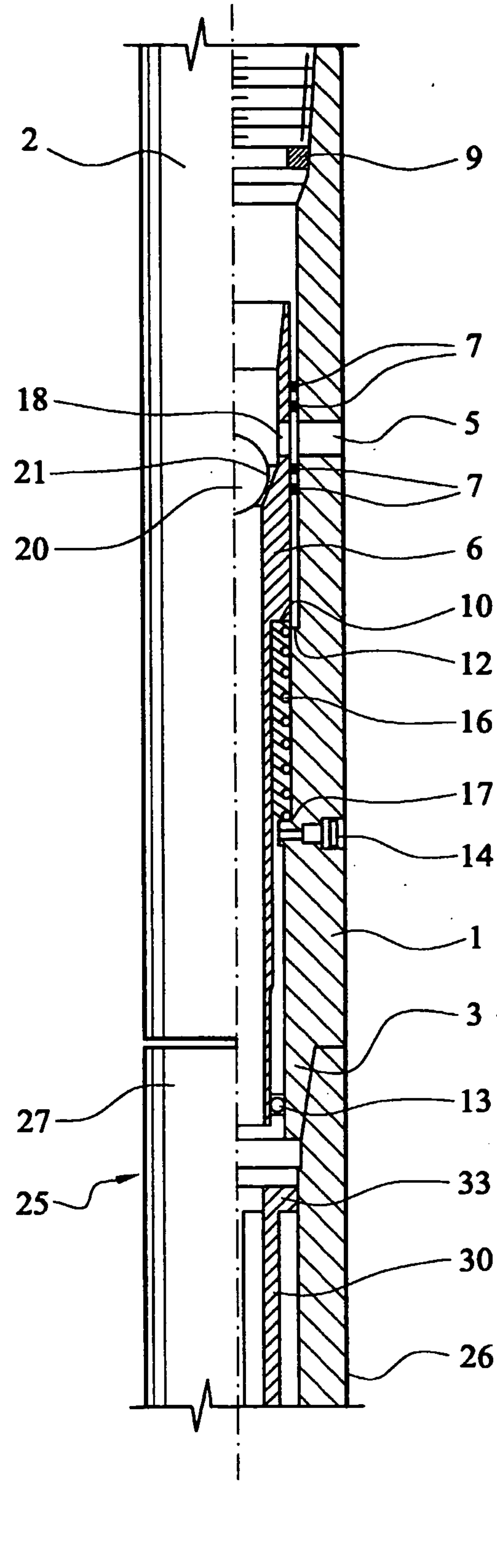
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FIG. 2

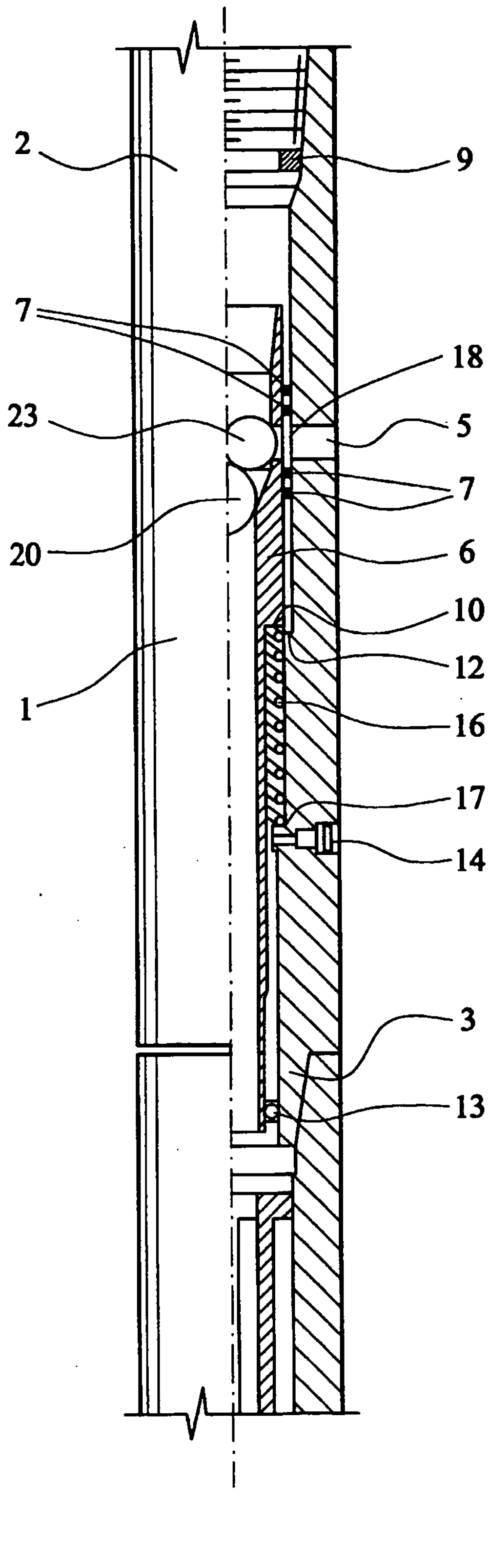
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FIG. 3

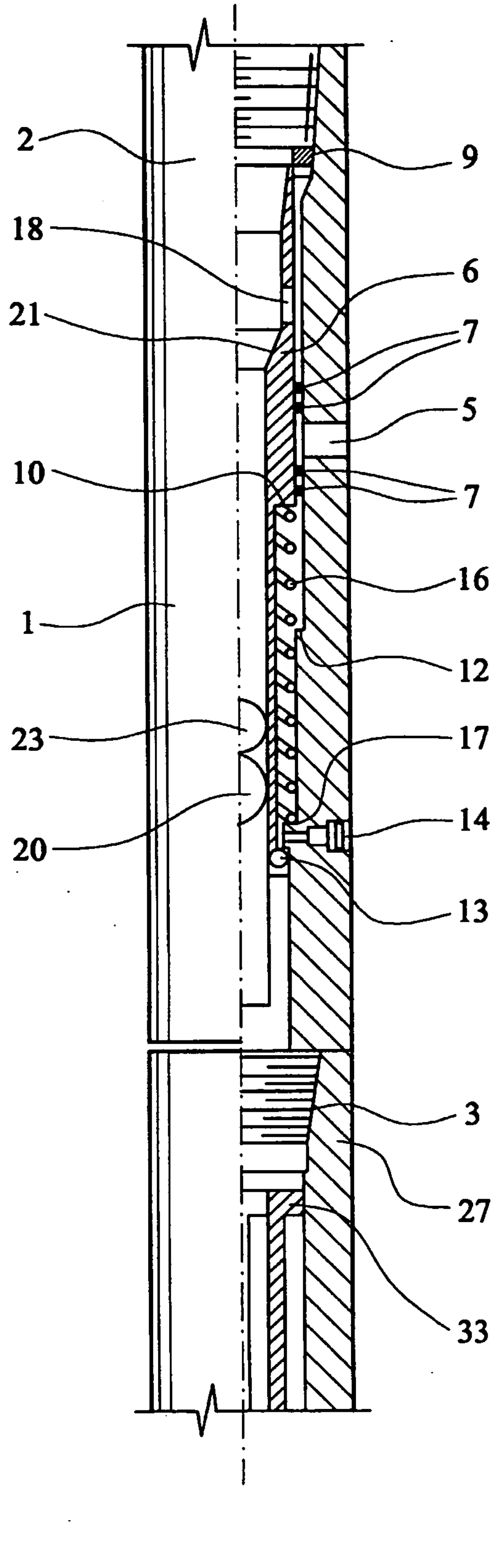
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FIG. 4

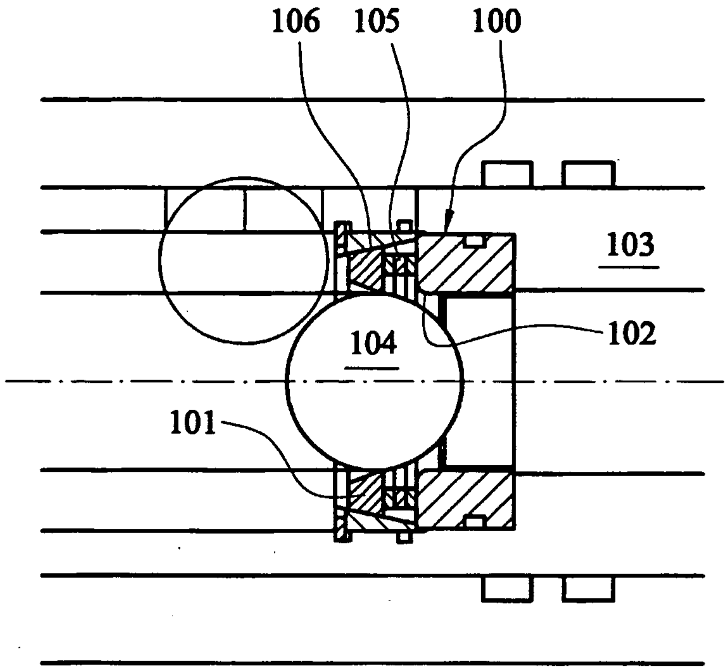

FIG. 5

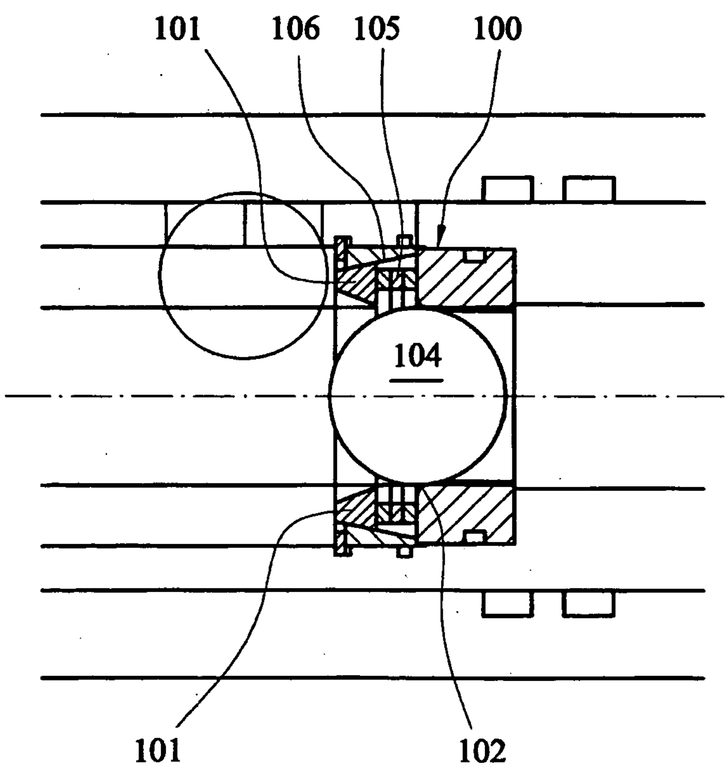

FIG. 6

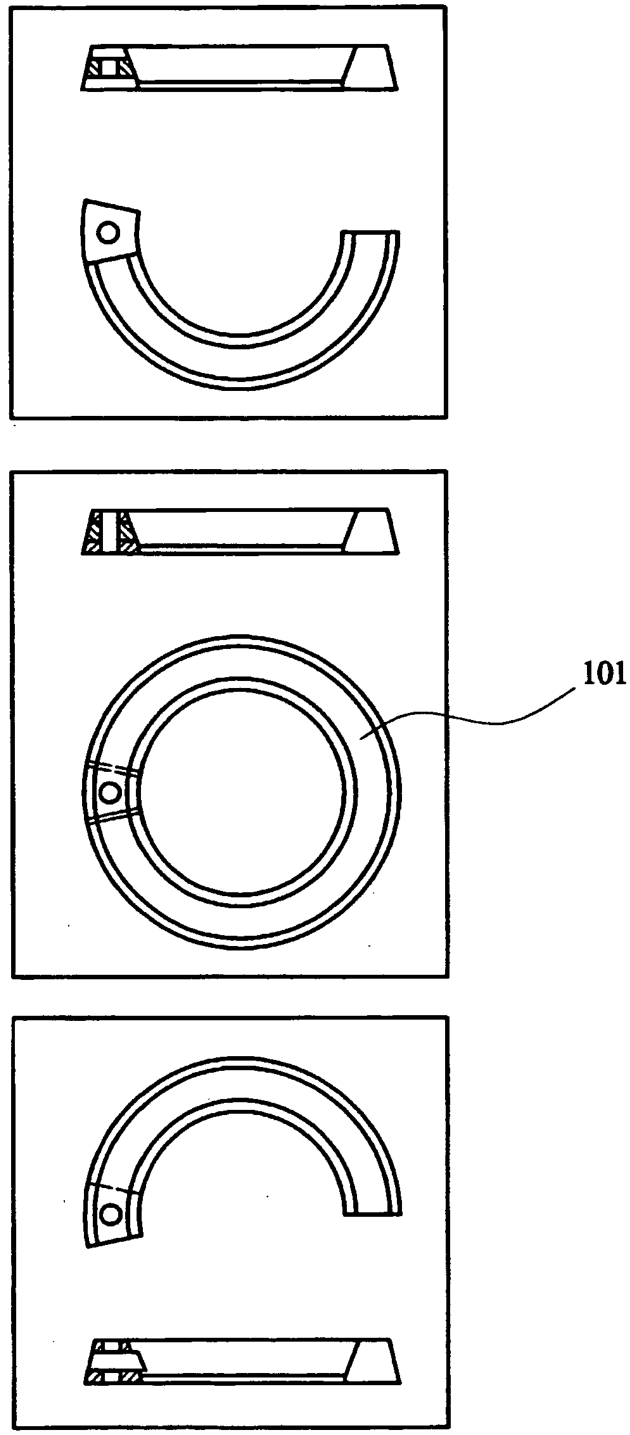

FIG. 7

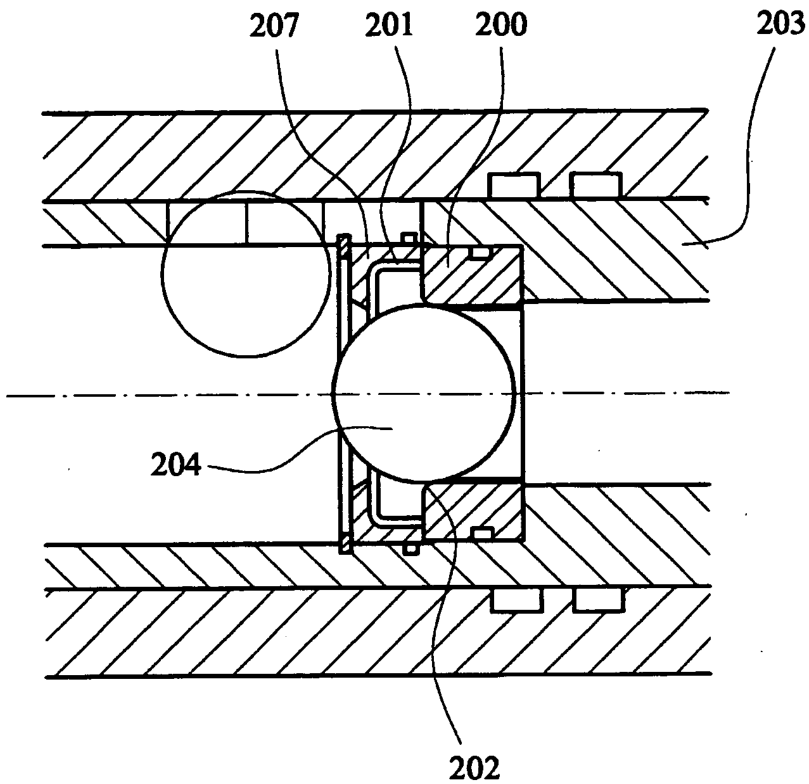

FIG. 8

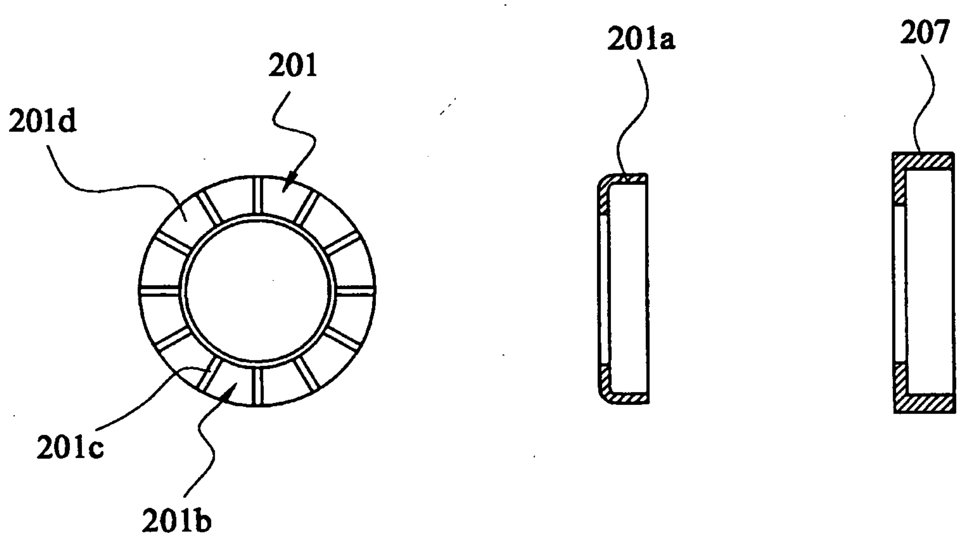

FIG. 9

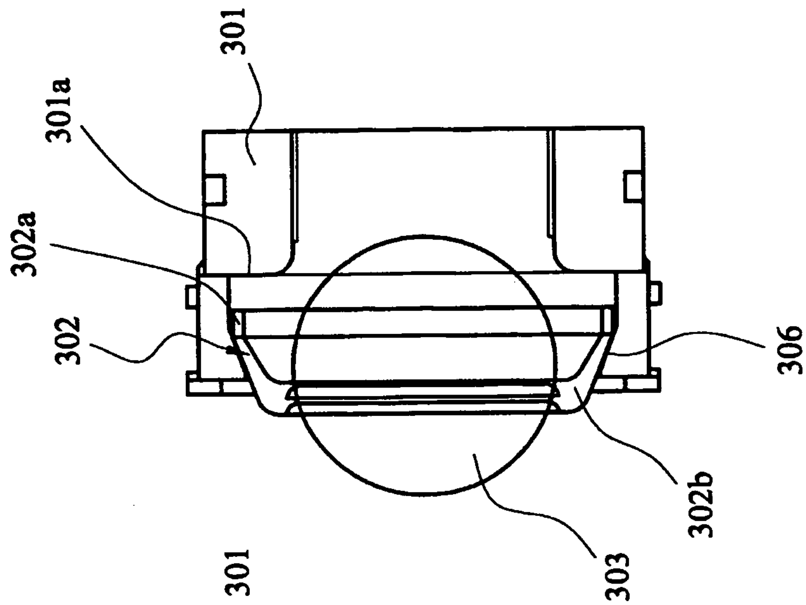

FIG. 10(c)

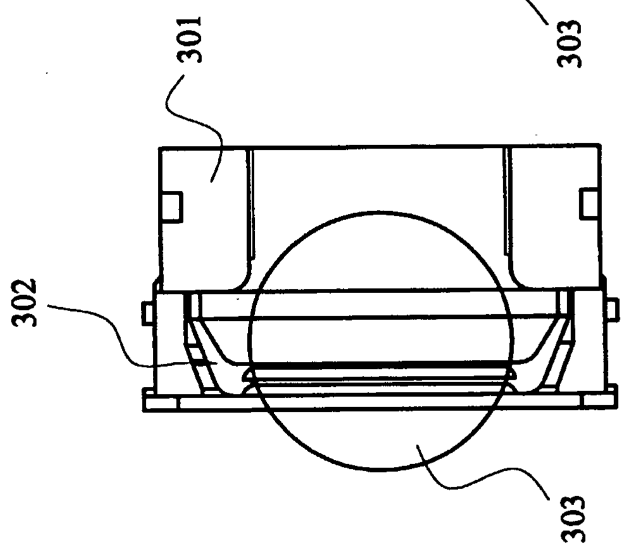

FIG. 10(b)

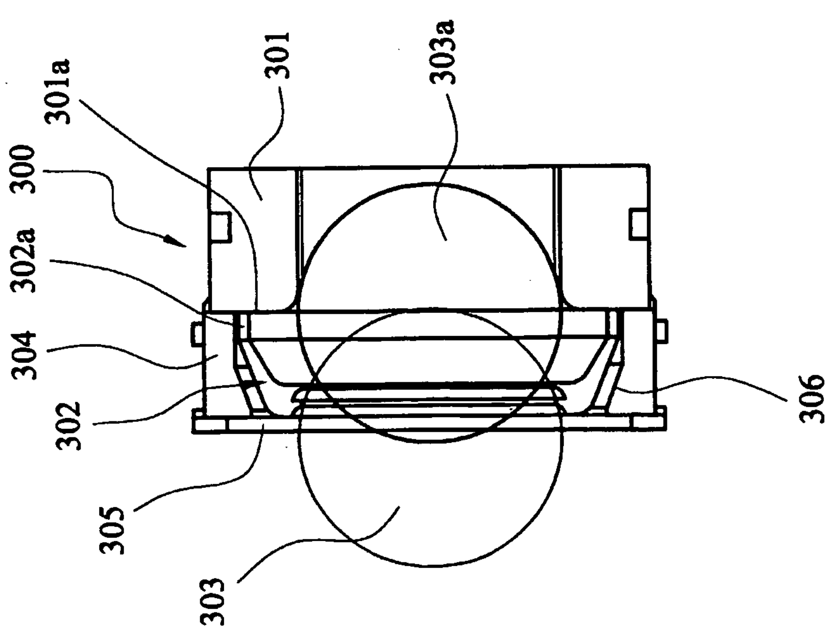

FIG. 10(a)

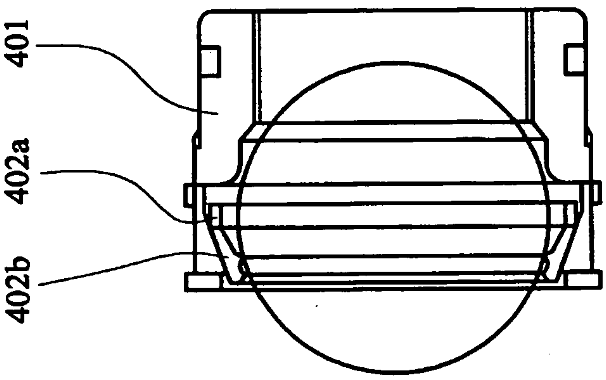

FIG. 11(c)

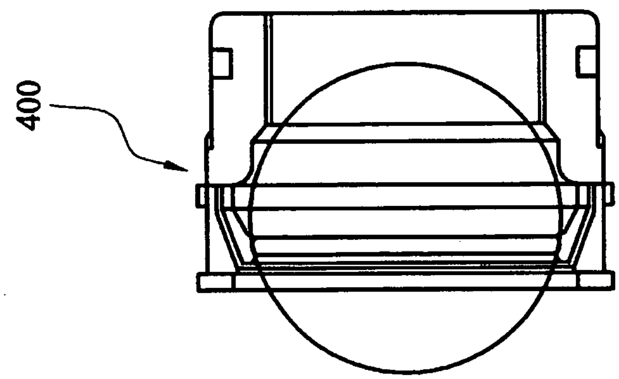

FIG. 11(b)

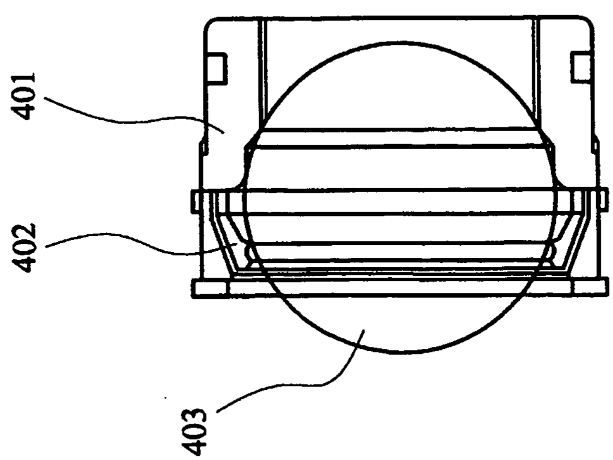

FIG. 11(a)